EVALUATION OF FIRE RETARDANT TREATED 100% COTTON OPEN-END DENIMS

NAVY CLOTHING AND TEXTILE RESEARCH FACILITY

NATICK, MASSACHUSETTS

TECHNICAL REPORT NO. NCTRF 190

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
30 Sep 90

3. REPORT TYPE AND DATES COVERED
Final from Jun 88 to Sep 90

4. TITLE AND SUBTITLE
Evaluation of Fire Retardant Treated 100% Cotton Open-End Denims

5. FUNDING NUMBERS
29-2-54-03

6. AUTHOR(S)
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7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

8. PERFORMING ORGANIZATION REPORT NUMBER
NCTRF Technical Report No. 190

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
Navy Clothing and Textile Research Facility
P.O. Box 59
Natick, Massachusetts 01760-0001

10. SPONSORING/MONITORING AGENCY REPORT NUMBER

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT

12b. DISTRIBUTION CODE

This report discusses the evaluation of

13. ABSTRACT *(Maximum 200 words)*
The Navy Clothing and Textile Research Facility evaluated various fire retardant treated 100% cotton denim fabrics manufactured from open-end spun yarns. The open-end denim fabrics were compared to the currently specified ring-spun denim for use in the Navy's shipboard utility trousers. Based on laboratory and wear test results, the use of open-end denim material in the manufacture of Navy utility trousers would not compromise quality, and would serve to broaden the source of supply.

14. SUBJECT TERMS
open-end spinning
ring-spun yarns
fire retardant treated denim

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT

18. SECURITY CLASSIFICATION OF THIS PAGE

19. SECURITY CLASSIFICATION OF ABSTRACT

20. LIMITATION OF ABSTRACT

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EVALUATION OF FIRE RETARDANT TREATED 100% COTTON OPEN-END DENIMS

INTRODUCTION

The Navy Clothing and Textile Research Facility conducted an extensive investigation of fire retardant treated (FRT) 100% cotton denim fabrics produced from open-end yarns. This investigation was initiated as a result of the denim industry approaching almost 100% transition from the use of ring-spun to open-end spun yarns in the manufacture of denims. The industry's transition was prompted by cost savings, and improved fabric uniformity. As a result of this industry trend, ring-spun FRT denim fabric, which is presently being used in the manufacture of shipboard utility trousers, dwindled to one source of supply. Since existing FRT denim specification requirements reflect the use of ring-spun yarns (in warp direction only), the investigation reported herein, evaluates the performance of denims produced with open-end yarns in both the warp and filling in order to broaden the Navy's current procurement base.

The evaluation included FRT open-end denim fabrics of varying weights, constructions, and weaves. The fabrics were solicited from four major denim suppliers. These fabrics were subjected to laboratory testing for their physical characteristics, flame resistance, and dimensional stability. The above properties were compared to those conforming to Cloth, Denim, Cotton, (Flame Retardant Treated), MIL-C-24915, (the fabric presently used to manufacture the Navy's FRT denim trousers).

Based on laboratory results, the three candidate fabrics which most closely met the current MIL-C-24915 requirements were selected and manufactured into utility trousers. The experimental trousers, along with "standard" (constructed with ring-spun yarns) FRT denim trousers were distributed to shipboard personnel for a six month user evaluation. At the conclusion of the user evaluation, physical testing for strength and abrasion properties was performed on a sampling of experimental and standard trousers. Data were also obtained from the test participants, regarding garment performance and user preference.

This report includes background information relating to this investigation, description of all candidate fabrics employed, the procedures used to evaluate the candidate fabrics, results obtained, and the conclusions and recommendations derived from these results.

BACKGROUND

The majority of yarns produced today are spun by using one of two methods: ring spinning or open-end spinning. Currently, in order to meet all the fabric strength requirements cited in MIL-C-24915, it is necessary to utilize ring-spun yarns in the warp direction (ring-spun yarns are generally stronger than open-end spun yarns). The present requirements were based on the evaluation of ring-spun fabrics, since at the time of development (early 1980's), 100% cotton open-end spun denims were only available in the 13-14 oz/yd^2 range, vis a vis 10 oz/yd^2 for a 100% cotton ring spun denim. This was due to the limits in open-end yarn technology at the time, which necessitated the construction of heavier fabrics to compensate for the weaker open-end yarns. Since then, open-end spinning technology has improved, as well as means to more efficiently select cotton fibers for use in high strength yarns. Also, at the time the specification requirements were developed, there were three major sources of supply for 100% cotton FRT ring-spun denim fabrics. Today, approximately 85% of the nine largest domestic denim suppliers utilize open-end yarns in production, while there is only one source of 100% cotton FRT ring spun denim fabric. Since one of the primary goals of government procurement is competitive bidding, this evaluation was conducted to compare the characteristics of open-end versus ring spun denims.

Our decision to consider the use of open-end yarns in the manufacture of FRT denim fabric for Navy use was also based on the results of a previous wear test evaluation of open-end and ring-spun denim trousers. The wear test was conducted by the University of California (1). Results of the University of California test indicated that "the ring-spun fabric was more durable than the open-end fabric, but the differences were small, and durability of both fabrics was acceptable to consumers".

MATERIAL DESCRIPTION

The current fabric utilized in men's and women's shipboard utility trousers is a FRT 100% cotton ring spun denim twill, conforming to MIL-C-24915. Ten open-end denim candidate fabrics were procured from three manufacturers, in varying weights, constructions and weaves. All candidate fabrics were subjected to laboratory evaluation. Results from this evaluation are reported in Appendix A. Although candidate denim fabrics with a 3/1 twill construction were procured in hope of enhancing strength characteristics, the visual difference, when compared to the currently specified 2/1 twill was objectionable. This difference would be particularly noticeable during an inspection line up.

Three of the ten candidate fabrics were selected for fabrication into trousers for the user evaluation. This selection was based on the fabric from each participating supplier possessing the 2/1 twill construction, and most closely conforming to the currently procured ring spun denim. Each supplier was represented in order to achieve a good sampling of industry production.

The three FRT 100% cotton denim candidate fabrics selected for the user evaluation were: Westex, Inc. (Avondale) #2341*, Swift Textile #5345, and Riegel #TSHS. Table I lists the properties of these materials. All candidate denim fabrics were finished by the precondensate ammonia cured process, which is the same treatment that the present standard denim undergoes. This treatment is durable to a minimum of 50 launderings.

*this fabric was constructed by Avondale Mills, and the fire retardant treatment was applied by Westex, Inc.

Table - I

Physical Characteristics of Candidate Materials

Characteristic	Westex	Fabric Swift	Riegel	Standard	MIL-C-24915 Requirements
Weave	2/1 RHT	2/1 RHT	2/1 RHT	2/1 RHT	2/1 RHT
Weight, finished (oz/yd^2)	10.7	12.0	11.5	12.0	12.5 (max.)
Yarns per Inch					
Warp	69	69	68	68	68 (min.)
Filling	38	45	45	44	42 (min.)
Air Permeability ($ft^3/sec/ft^2$)	29	9	22	17	9 (min.)
Break Strength (lbs)					
Warp	156	187.8	132.3	194	160 (min.)
Filling	100	101.2	110.7	137	100 (min.)
Tear Strength (lbs)					
Warp	7.6	7.8	5.6	8.7	7 (min.)
Filling	7.7	5.7	7	7.8	5 (min.)
Stiffness (in. lbs)					
Warp	.0059	.0050	.0077	.0157	.015 (max.)
Filling	.0082	.0036	.0042	.0088	.010 (max.)
Colorfastness to:					
Light (40 SFH)	poor	excellent	good	good	good (min.)
Laundering (3 cycles)	poor	excellent	good	good	fair (min.)
Perspiration					
Acid	excellent	excellent	excellent	excellent	good (min.)
Alkaline	excellent	excellent	excellent	excellent	good (min.)
Crocking					
Wet	1-2	2	1	1	1.5 (min.)
Dry	2-3	4	4	2	3.0 (min.)
Seam Efficiency (%)	102	100	N/A	102	80 (min.)

N/A - not available

Table - I

Physical Characteristics of Candidate Materials (cont'd)

Characteristic	Fabric Westex	Swift	Riegel	Standard	MIL-C-24915 Requirements
pH	6.8	5.6	6.1	5.8	5 to 8.5
Dimensional Stability (%)					
Warp (TM5550, 1 cycle)	5.1	3.5	2.0	3.5	3 (max.)
Filling	1.7	1.0	0.9	1.8	3 (max.)
Dimensional Stability (%) (progressive, TM5556)					
After 5 cycles					
Warp	4.7	1.7	-2.6	0.7	-
Filling	1.1	1.0	0.6	0.75	-
After 10 cycles					
Warp	6.3	3.2	-1.6	2.0	-
Filling	1.3	1.5	0.7	1.2	-
Flame Resistance (Initial)					
Warp					
After flame (sec)	0.0	0.0	0.0	0.0	2 (max.)
After glow (sec)	1.5	2.3	1.8	2.0	5 (max.)
Char length (in.)	2.4	2.8	2.3	3.2	5 (max.)
Filling					
After flame (sec)	0.0	0.0	0.0	0.0	2 (max.)
After glow (sec)	1.6	2.0	1.5	0.8	5 (max.)
Char length (in.)	3.5	2.7	2.5	2.9	5 (max.)
(After 10 launderings of TM5556)					
Warp					
After flame (sec)	1.2	2.0	0.6	0.2	2 (max.)
After glow (sec)	1.6	8.5	3.0	3.2	5 (max.)
Char length (in.)	4.0	3.0	4.7	3.5	5 (max.)
Filling					
After flame (sec)	0.0	0.5	0.3	0.0	2 (max.)
After glow (sec)	2.3	4.6	2.9	2.5	5 (max.)
Char length (in.)	3.5	3.4	4.2	3.0	5 (max.)
Abrasion Resistance					
Warp	2355	3111	2479	2659	*
Filling	1479	3253	2969	2858	*

*There are currently no requirements for abrasion resistance.

PROCEDURE

Laboratory Evaluation

The results of the laboratory evaluation of the three candidate fabrics and the present standard fabric are listed in Table I. Testing was performed in acccordance with the test methods listed in Table II. Note that dimensional stability and fire retardancy testing after laundering was limited to 10 cycles. Since the type of yarn processing has no effect on the FR treatment (2), 10 cycles were performed due to time and manpower constraints.

Table - II

Laboratory Test Methods

Characteristic	Test Method *
Weave	Visual
Weight	5041
Yarns per inch	5050
Air Permeability	5450
Break Strength	5100
Tear Strength	D-1424/ASTM
Stiffness	5202
Colorfastness to:	
Light	5660
Laundering	5610
Perspiration	5680
Crocking	AATCC-8
Seam Efficiency	5110
pH	2811
Dimensional Stability	5550
Dimensional Stability (progressive)	5556
Flame Resistance	5903
Flame Resistance after 10 Launderings	5556 & 5903
Abrasion Resistance	5300

* Federal Standard for Textile Test Methods no. 191A, except where noted

User Evaluation

The user evaluation was conducted for a six month duration onboard the USS KAUFFMAN and USS CONNOLE. Both ships use Newport, RI as their home port. Trousers were manufactured from the experimental fabrics listed in Table I. A total of fifty test participants were briefed as to the purpose of the evaluation. Each test participant was then fitted with one pair of experimental and one pair of standard denim trousers. Participants were informed to wear trousers alternately, and as often as possible. Questionnaires and laundering instructions were provided with the trousers. Each test site was assigned a Test Monitor for supervision of test protocol, and to resolve any potential problems.

PROCEDURE

User Evaluation (cont'd)

Questionnaire forms (Appendix B) addressed characteristics in the following areas:

a. Number of times worn each week
b. Method of cleaning
c. Dimensional stability
d. Difficulty with spot and stain removal
e. Appearance after repeated wear and cleaning
f. Comfort
g. Durability
h. Exposure to extreme heat or flame
i. Preference

Physical Testing After User Evaluation

Physical testing was performed on the standard and experimental trousers that were subjected to the six month user evaluation. Due to the Persian Gulf crisis, only trousers from the USS KAUFFMAN could be recovered for examination. Besides undergoing visual examination, the test trousers (Westex, Swift, Riegel and Standard) were evaluated for tensile, tear and abrasion resistance properties. A sampling plan was formulated in order to perform testing of both "worn" and "unworn" areas of the trousers. Results are reported as an average of all areas of the garments tested. User evaluation trousers were tested in accordance to the test procedures listed below:

Characteristic	Test Method *
Break Strength	5100
Tear Strength	D-1424/ASTM
Abrasion Resistance	5300

* Federal Standard for Textile Test Method No. 191A, except where noted

RESULTS/DISCUSSION

Laboratory Evaluation

As can be seen in Table I, all candidate fabrics were found to meet the established specification requirements of MIL-C-24915 with respect to weave, air permeability, stiffness, seam efficiency, pH, colorfastness to perspiration, tear and break strength (filling direction only). Although the rating for colorfastness to crocking for both the Westex and Riegel denims did not meet current requirements, results were found to be marginally acceptable. The Westex denim fabric received poor colorfastness ratings for laundering (3 cycles) and light, after exposure to 40 standard fading hours. Dimensional stability for all candidate fabrics met current specification requirements with exception for the Westex and Swift denims fabrics, which failed in the warp direction only. The tear and break strengths (warp only) for Westex and Riegel denim fabrics were lower than the cited requirements.

As noted earlier, open-end denim fabrics tend to exhibit lower strength characteristics in such areas as tensile, tear and abrasion (when compared to ring spun denim). All candidate denim fabrics were therefore evaluated for abrasion resistance, even though there currently exists no requirement for this characteristic. As indicated in Table I, abrasion resistance results for the candidate fabrics were generally lower (warp direction only) than those of the standard "ring-spun" denim (the standard denim is constructed with open-end yarns in the filling direction).

All candidate fabrics met the specification requirements for flame resistance, with the exception of the Swift denim, which experienced afterglow failures in the warp direction after laundering. These failures, which are minor in nature, can be attributed to finishing technique, since this was Swift's first attempt at fire retardant-treating denim.

Based on the above physical and flammability results, the only specification requirements likely to be subjected to slight modification would be weight (higher finished weight limit) and strength (lower tear strength limit). Although the candidate fabrics either met the present requirements, or were slightly lower, modification of these two areas will allow for production variation.

User Evaluation

Due to the recent Persian Gulf crisis, results reported in Table III reflect input from only the USS KAUFFMAN. The data shown indicate the percentage of the total response to a characteristic addressed for both the standard and experimental trousers. The three types of experimental trousers are reported as a combined percentage because of the extreme similarity between responses.

Times worn each week - Both the standard and experimental trousers were each worn approximately two times per week.

RESULTS/DISCUSSION

User Evaluation (cont'd)

Cleaning method - All respondents reported that both their standard and experimental trousers were laundered in automatic home washers and shipboard machines.

Dimensional stability - As is typical with laundering of 100% cotton jeans, 32 percent of respondents reported some shrinkage after laundering with the experimental trousers, while 21 percent of the participants reported shrinkage with the standard trousers.

Spot/stain removal - Sixty three and 79 percent of those wearing the experimental and standard trousers respectively, reported that spots were removed in laundering. Those who stated that stains and spots were not removed, cited paint, grease, synthetic oil and shoe polish as problem contributers.

Appearance after repeated wear & cleaning - Seventy nine percent of the experimental trousers received either "excellent" or "good" ratings for appearance after repeated wear and cleanings. Only 63% of the test participants, however, gave the standard trousers either an "excellent" or "good" rating.

Comfort - Participants were asked to rate the comfort of the trousers under the conditions worn. The majority of the respondents rated both the standard and experimental trousers "excellent" or "cool". Thirty two percent and 11% of the participants indicated a "warm" rating for the experimental and standard trousers, respectively. None of the trousers evaluated received a "hot" rating.

Durability - Durability ratings were high for both the experimental and standard trousers, receiving "excellent" or "good" ratings of 90% and 84%, respectively. The one respondent that rated the standard trousers "poor", indicated that this was due to a broken zipper.

Extreme heat or flame exposure - Only one participant reported that both his standard and experimental trousers were subjected to heat and flame during his work as a welder. He reported that there was no effect on either type of trousers.

Preference - When participants were asked which trousers they preferred, the majority of the respondents either preferred the experimental (47%) or had no preference (37%). Only 16% of the respondents preferred the standard trousers over the experimental trousers. Most participants did not comment on their decision regarding preference. Of those who did comment on the experimental trousers, the following was provided: "experimental trousers much more comfortable then regular, came back from ships laundry much nicer/softer", "The experimental seem to be more comfortable", and "experimental held their color better and generally held up better than the standard".

Table III

Questionnaire Data From User Evaluation

Characteristic	Descriptor	Experimental	Standard
# of times worn each week	Average	2	2
Cleaning (%) method	home laundering	40	40
	shipboard	60	60
Dimensional stability problems (%)	yes	32	21
	no	68	79
Spot/ stain removal problems (%)	yes	37	21
	no	63	79
Appearance after repeated wear & cleanings (%)	excellent	16	11
	good	63	52
	fair	21	32
	poor	0	5
Comfort (%)	excellent	16	5
	cool	52	84
	warm	32	11
	hot	0	0
Durability (%)	excellent	16	16
	good	74	68
	fair	10	11
	poor	0	5

	Experimental	Standard	No Preference
Preference (%)	47	16	37

RESULTS/DISCUSSION

Physical Testing After User Evaluation

Table IV indicates the difference in strength/durability characteristcs for each of the candidate fabrics before and after the user evaluation. Break strength after wear results for each material were generally less than initial (before wear) results. The Riegel fabric suffered the greatest loss (18% in the warp direction). Tear strength after wear results varied. Both the Westex and the standard fabrics sustained strength losses, while the Swift and Riegel fabrics enjoyed strength gains. The standard fabric's loss in tear strength was significant (16% in the warp and 9% in the filling). Conversely, the Swift fabric's strength gain was also significant (15% in the warp and 22% in the filling).

Results of abrasion resistance tests after wear varied. The Westex fabric sustained a relatively high gain (12%) in abrasion resistance in the warp direction and a significant loss (23%) in abrasion in the filling direction. The high loss in abrasion resistance of the Westex fabric can possibly be attributed to the fabric's relatively loose construction (low picks per inch). In one case (Swift fabric), there was a significant gain (39%) in abrasion resistance in the warp direction, and virtually no change (2%) in abrasion resistance in the filling direction. The Riegel fabric sustained the opposite results of the Swift fabric, i.e., the Riegel fabric's abrasion resistance after wear in the warp direction was unchanged (1%) but suffered a significant loss (23%) in the filling direction. The most suprising results were recorded for the standard fabric, where there was a significant loss in abrasion resistance in both the warp (21%) and filling (16%) directions. It should be noted, however, that despite the standard fabric's high loss of abrasion resistance, the overall values are still comparable to those of the open-end fabrics.

The increase in both tear strength and abrasion resistance experienced by the open-end fabrics is somewhat difficult to explain. The most logical theory would have been that shrinkage incurred during laundering tightened the fabric sufficiently to enhance tear strength and abrasion resistance. If this was the case, however, all fabrics would have reacted similarly, since all fabrics experienced similar degrees of shrinkage. Consequently, the only logical explanation that can be offered is that open-end yarns tend to make the fabric initially stiffer than a comparable ring-spun fabric. Subsequent laundering softens the open-end fabric considerably, making the yarns more pliable, and consequently, less subject to degradation. This softening of the fabric was observed during our laboratory evaluation and was subsequently reported by wear test participants. Based on laboratory and wear test results, the ring spun fabric did not appear to have softened as much as the open-end fabrics after laundering.

Table - IV

Strength/Durability Characteristics of Materials After User Evaluation

Characteristic	Fabric							
	Westex		Swift		Riegel		Standard	
	W 1/	F 2/	W	F	W	F	W	F
Break Strength								
Initial (lbs)	156	100	188	101	160	111	187	123
After wear test (lbs)	143	93	183	105	131	115	171	123
Percent difference	-8	-7	-2	+4	-18	+4	-9	0
Tear Strength								
Initial (lbs)	7.6	7.7	7.8	5.7	5.6	7.0	9.2	8.1
After wear test (lbs)	7.2	7.3	9.2	7.3	5.8	8.0	7.7	7.4
Percent difference	-5	-5	+15	+22	+3	+12	-16	-9
Abrasion Resistance 3/								
Initial	2355	1479	3111	3253	2479	2969	3906	2566
After wear test	2666	1123	5126	3305	2497	2290	3102	2155
Percent difference	+12	-24	+39	+2	+1	-23	-21	-16

1/ Warp direction
2/ Filling direction
3/ cycles to destruction

CONCLUSIONS

- Laboratory results from unworn candidate open-end denim fabrics generally indicated lower abrasion resistance and lower break and tear strengths (warp direction only), when compared to the standard ring-spun denim. Both the experimental and standard trousers, however, received high ratings for durability and appearance after repeated wear and laundering.

- The majority of the user evaluation respondents preferred the "experimental trousers" or stated "no preference". Consequently, open-end fabric "deficencies" which were exhibited during the laboratory evaluation, were not perceived by the test participants during the six month user evaluation.

- Physical testing performed on the worn user evaluation trousers for strength/durability, indicated varied results. Break strengths for both experimental and standard trousers were generally less than initial. After repeated wear and launderings, two out of the three types of experimental trousers exhibited an increase in tear strength, while the standard trousers experienced a strength loss. Abrasion resistance also increased for the majority of the open-end experimental trousers, while again, the standard trousers decreased significantly. Although the standard trousers' strength and durability characteristics depreciated after wear and laundering, the overall values remained comparable to those of the open-end trousers.

- Based on the above, it appears that although denim fabrics constructed with open-end spun yarns initially possess lower strength and abrasion resistance characteristics than ring-spun denims, the disparities are reduced significantly after repeated wear and laundering. This results in little or no difference in overall garment durability between open-end and ring-spun denims.

RECOMMENDATIONS

Based on overall laboratory and user data, it is recommended that MIL-C-24915 be modified to permit the use of open-end spun yarns in the production of fire retardant treated 100% cotton denim for Navy utility trousers. Since strength deficiencies only occurred in the warp direction for some of the candidate fabrics, two actions will be proposed:

1. The weight of the denim will be slightly increased to 12.5 ± 1 oz/yd^2 (from 11.5 to 12.5 oz/yd^2). This weight increase will aide suppliers that are marginally meeting strength requirements.

2. The break strength requirement for warp direction only will be lowered to 130 lbs (min.) from the present 160 lbs (min.), and the tear strength requirement for the warp direction will be lowered to 5 lbs (min.) from the present 7 lbs (min.).

Although the candidate fabrics either met the present requirements, or were slightly lower, modification of these two areas will allow for production variation. These modifications cited above should serve to broaden the Navy's current supply base without compromising quality of the protective trousers worn by shipboard personnel.

Acknowledgments

Appreciation is extended to both Ms. Karen Boyd and Ms. Betsy Abaldo of the Navy Clothing & Textile Research Facility, for their performance of numerous laundering cycles and physical testing.

References

1. Morris, M. A. and Prato, H. H., End Use Performance and Consumer Acceptance of Denim Fabrics Woven from Open-End and Ring-Spun Yarns, "Textile Research Journal" pp 177-183 March 1978

2. Telephone conversation between M. Roy, Navy Clothing and Textile Research Facility and Robert Harper, Southern Regional Research Center on May 9, 1990

APPENDIX A

OPEN END DENIM EVALUATION
PHYSICAL CHARACTERISTICS

Test Method	Characteristic	Swift 25101	Riegel TSRS	Westex 2826 (Cone)	Westex 15-24 (Cone)	Westex 1357-8 (Avondale)	Westex 2323 (Avondale)	Westex 2317-8 (Avondale)
Visual	Weave	2/1 RHT	2/1 RHT	3/1 RHT	2/1 RHT	3/1 RHT	2/1 RHT	3/1 RHT
5041	Weight, finished (oz/yd^2)	12.1	9.9	12.2	10.3	16.2	10.1	12.4
5050	Yarns per Inch							
	Warp	69	68	72	67	60	70	60
	Filling	44	46	43	41	43	37	38
5450	Air Permeability (ft3/sec/ft2)	9	32	16	13	6	25	10
5100	Break Strength (lbs)							
	Warp	190	131	174	160	214	161	214
	Filling	116	78	112	87	169	81	90
D-1424	Tear Strength (lbs)							
	Warp	7.9	6.5	9.4	8.5	11.8	8.4	resisted tear
	Filling	6.2	4.9	7.7	5.9	10.6	5.6	7.7
5202	Stiffness (in. lbs)							
	Warp	.0047	.0074	.0087	.0069	.0116	.0065	.0062
	Filling	.0034	.0049	.0051	.0019	.0139	.0053	.0043
	Colorfastness to:							
5660	Light (40 SFH)	E	E	E	G	E	F	G
5610	Laundering (3 cycles)	E	E	E	G	G	G	E
5680	Perspiration							
	Acid	E	E	E	E	E	E	E
	Alkaline	E	E	E	E	E	E	E
AATCC-8	Crocking							
	Wet	2-3	1-2	1	1-2	1-2	1-2	1-2
	Dry	4-5	4	2-3	2-3	3	3	2-3
5110	Seam Efficiency (%)	100	N/A	100	100	104	111	106
2811	pH	5.4	6.6	6.3	6.3	6.1	7.1	6.1

E - excellent, G - good, F - fair

OPEN END DENIM EVALUATION
PHYSICAL CHARACTERISTICS (cont'd)

Test Method	Characteristic	Swift 25101	Riegel TSRS	Westex 2826 (Cone)	Westex 15-24 (Cone)	Westex 1357-8 (Avondale)	Westex 2323 (Avondale)	Westex 2317-8 (Avondale)
5550	Dimensional Stability (%) (1 cycle)							
	Warp	N/A	-1	5	6	-1	5	8
	Filling	N/A	2	2	1	2	1	2
5556	Dimensional Stability (%)							
	After 5 cycles							
	Warp	3	-2	5	4	-2	5	8
	Filling	1	1	2	1	2	0	1
	After 10 cycles							
	Warp	4	-1	6	5	-1	6	10
	Filling	1	1	2	1	3	1	2
5903	Flame Resistance (Initial)							
	Warp							
	After flame (sec)	0	0	0	0	0	0	0
	After glow (sec)	2	2	2	1	2	2	2
	Char length (")	3	3	2	3	1	3	3
	Filling							
	After flame (sec)	0	0	0	0	0	0	0
	After glow (sec)	2	2	1	1	2	1	2
	Char length (")	3	3	2	2	1	3	2
	(After 10 launderings of TM5556)							
	Warp							
	After flame (sec)	0	0	0	0	0	5	0
	After glow (sec)	10	3	3	3	27	2	7
	Char length (")	3	4	3	4	2	6	3
	Filling							
	After flame (sec)	1	0	0	0	0	0	0
	After glow (sec)	5	3	2	2	33	3	10
	Char length (")	4	4	3	4	2	5	3
5300	Abrasion Resistance							
	Warp	2481	3030	1886	2339	2893	2105	3669
	Filling	3384	2870	2415	1552	2601	1245	2069

APPENDIX B

NAVY CLOTHING AND TEXTILE RESEARCH FACILITY
NATICK, MASSACHUSETTS 01760

Evaluation of Experimental Fire Retardant Utility Trousers

This Facility has recently completed an evaluation on fire retardant denim materials produced with a different type of yarn than that specified for the current fire retardant utility trouser. This investigation was prompted by the denim industry's transition to a different type of yarn to save time, decrease defect levels and save money.

The objective of the wear test is to evaluate the durability and acceptability of utility trousers produced with the new yarn. The trousers issued for the wear test are identical in design to the FR trousers you currently wear, only the fabric differs.

You will be issued two trousers: standard trousers and experimental trousers identified by a designating letter. You are requested to wear the trousers alternately and as often as possible. These trousers should be worn under actual operating conditions and you should maintain a weekly record indicating number of times worn and how they are laundered. Your personal opinions and comments on the questionnaires are important in determining the experimental trousers' performance and acceptability. The questionnaire seeks your opinion regarding comfort, durablility, dimensional stability (shrinkage), and overall acceptablity.

The wear test will be conducted over a six month period. At the end of the wear test, NCTRF representatives will meet with all test participants to personally discuss your opinion of the trousers and to review the completed questionnaire.

Your cooperation and assistance in this project is appreciated. If there are any further questions, contact your test monitor or Michelle Cooper at (508) 651-4189.

NAVY CLOTHING AND TEXTILE RESEARCH FACILITY
NATICK, MASSACHUSETTS 01760-2490

WEAR TEST QUESTIONNAIRE OF FR DENIM UTILITY TROUSERS

Please complete this questionnaire concerning the trousers you are testing after wearing the items three months.

NAME/RANK____

SHIP/STATION____

SIZE OF TROUSERS/EXPERIMENTAL TROUSERS LETTER________________

1. What duties do you perform?________________________________

____

____

2. Number of times trousers worn each week.

Standard trousers__________ Experimental trousers__________

3. Method of cleaning and number of times cleaned each week.

Standard Trousers: Dryclean_____ Shipboard_____ Home washer_____ Hand_____

Experimental Trousers: Dryclean_____ Shipboard_____ Home washer_____ Hand_____

4. Did trousers shrink after cleaning?

Standard trousers Yes_____ No_____

Experimental trousers Yes_____ No_____

If yes, to what degree?________________________________

____

5. Rate the appearance of the trousers after repeated wear and cleaning.

Standard trousers	POOR	FAIR	GOOD	EXCELLENT
Experimental trousers	POOR	FAIR	GOOD	EXCELLENT

6. Were spots and stains removed in cleaning?

Standard trousers Yes_______ No________

Experimental trousers Yes_______ No________

7. Rate the comfort of the trousers.

Standard trousers	HOT	WARM	COOL	EXCELLENT
Experimental trousers	HOT	WARM	COOL	EXCELLENT

If HOT or WARM, please describe the conditions (temperature and humidity) and types of discomfort____

____

8. How durable were the trousers to abrasion, rips/tears, etc?

Standard trousers	POOR	FAIR	GOOD	EXCELLENT
Experimental trousers	POOR	FAIR	GOOD	EXCELLENT

If FAIR or POOR, please explain________________________________

____

9. Were the trousers exposed or subjected to extreme heat or flame?

Standard trousers Yes_______ No________

Experimental trousers Yes_______ No________

If yes, please indicate conditions and describe any effect on the trousers ________________________________

____

10. Which trousers do you prefer?

Standard trousers   Experimental trousers   No preference

11. Additional comments ______________________________

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